

Industrial dynamics

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Overview

Industrial dynamics is basically dedicated to the study of the drivers of the evolution of industries. In this sense, the analysis of the dynamics of the industry seeks to capture major variables driving the processes of entry/exit, innovation and growth, and to understand their evolution over time. At a more aggregate level, industrial dynamics also seeks to analyse how the emergence, the development or the decline of various industries may influence the economic growth of modern economies. Whatever the chosen level of analysis, the study of industrial dynamics requires the collection of empirical evidence, firstly, to define major stylised facts and regularities of evolution, and secondly, to build a consistent analysis of why and how industries evolve and contribute to economic change. An increasing number of publications are available on this theme, but a full understanding of the dynamics and evolution of industries remains underdeveloped.

1 Introduction

Industrial dynamics focuses on the way in which the activities undertaken within the economic system are divided up among firms: some firms embrace many different activities while, for others, the range is narrowly circumscribed; some firms are large and others are small; some are vertically integrated but others are not. Industrial dynamics not only describes and analyses how the industry is organized now, but also how it differs from what it was in earlier periods: what forces were operative in bringing about this reorganization of the industry and how these forces have been changing over time. The study of industrial dynamics demands a permanent and sound connection between facts and theory. The stimulus provided by the patterns, puzzles and anomalies revealed by systematic data gathering and careful collection of detailed information is essential to make progress in the understanding of the forces which determine the dynamics of the industry.

Industrial dynamics is crucial for understanding the coherence that exists within a specific industry – for instance, what determines its boundaries, who does what and why within the industry, and what forces are central to its functioning – as well as the diversity which may be observed among different industries. Industrial dynamics requires a sound knowledge of the firms composing the industry and is intended to provide some guidelines for industrial and macroeconomic policies.

The object of this entry is to show that major advances have been made in the analysis of industrial dynamics since the 1980s. Nevertheless, much remains to be done. Three main elements will be considered here. Firstly, the study of industrial dynamics has not been constant over time. Despite early work that underlined the importance of industrial dynamics studies, work on this topic was sparse from the 1950s to the 1980s, a period in which mainstream industrial organization held centre stage in the economics literature. Secondly, knowledge concerning industrial dynamics is still partial. The renewed interest in the literature focuses on specific dimensions of industrial dynamics that are examined in depth. But other important dimensions are still emerging domains of research. The difficulty lies in the fact that industrial dynamics is closely linked to notions such as the processes of innovation and economic growth, the analysis of which generally requires the economist to go beyond the conventional teachings of mainstream industrial organization. Thirdly, in the age of globalization, the concept of a ‘national system of innovation’, which has been used to study how the coevolution of technologies and institutions favours economic growth, is now being questioned.

2 Emergence, decline and re-birth of industrial dynamics

Even if some authors such as Alfred Marshall (1890) and Joseph Schumpeter (1939) stressed the importance of studies in industrial dynamics, the economic literature from the 1950s to the 1980s turned essentially to the static analysis of structure, behaviour and performance (see MARSHALL, A.; SCHUMPETER, J.). Marshall, however, proposed many line of inquiry which could have been developed: the fact that the economy is composed of different sectors, the growth and decline of which is unequal and intrinsically dependent on the organization of knowledge; the fact that the growth of knowledge is linked to the ability of firms to ensure a coherence between

internal economies (organization and direction of the resources of the firm) and external economies (general development of the economy). Schumpeter also made significant work emphasizing the different forms of innovation and the role of the entrepreneur in this process. He made some crucial contributions to the analysis of the evolution of industry in a context of radical change and innovation. He stressed that specific forms of organization were useful to ensure the development through time of the industry.

These contributions, which provided first steps towards the elaboration of an industrial dynamics approach, were neglected, presumably because what was lacking in such a literature was a comprehensive theory that could analyse the determinants of the dynamics of the industry. Despite the willingness to deal with industrial dynamics in all its richness and complexity, these contributions were generally taken as descriptive, disparate, and not sufficient to analyse how the structures and forms of organization of industries changed over time. The need for a unified theoretical framework appeared a priority and emerged rapidly within mainstream industrial organization, with different and successive refinements. The post-Second World War decades were characterized by the development of analyses of industrial organization that focused on optimality properties and on comparative efficiency studies of different equilibrium situations, while ignoring the conditions under which an industry could emerge and evolve over time – the core conditions of industrial dynamics. This mainstream economic thinking prevailed in a period in which major changes were taking place in industry structure, economic growth and changes in industrial leadership on an international level, and despite the prior existence of the preliminary dynamic theories of economic development to be found especially in Marshall and Schumpeter. Within the mainstream perspective, from the late 1950s to the 1960s, the structure–conduct–performance paradigm, at the core of the Harvard tradition, focused essentially on the determinants of features of market structure and performance, such as concentration, firms' size and profitability. In the 1970s and the 1980s, this vision was challenged by the Chicago School and by the theory of 'contestable markets'. At the same time, the transaction cost approach reintroduced the important question of integration versus specialization (see COASE, R.; TRANSACTION COST ECONOMICS). Finally, the New Industrial Organization, using the apparatus of game theory, analysed the characteristics of different market behaviour where strategic interactions prevailed. These different analyses were major advances in the development of conventional industrial organization. But, in retrospect, they made meagre contributions to the specific problem of industrial dynamics; they were not based on a dynamic framework but on a static one (as in the Harvard tradition where production functions were left unexplained), or their unit of analysis was not the industry but transactions (as in the transaction cost approach) or rational behaviour (as in the New Industrial Organization) (see Krafft 2000).

A re-birth of industrial dynamics as an attractive field of investigation occurred in the 1980s through two lines of inquiry: the assessment of paradoxical stylised facts and the understanding of the life cycle of the industry. In the 1990s, a third line of inquiry emerged, spurred by empirical research that revealed in a systematic manner a significant gap between stylised facts about industrial dynamics and theories. This third dimension focuses especially on the understanding of the evolution of industry, and can be viewed as a new departure in the study of industrial organization that builds on the neglected work of Marshall and Schumpeter.

3 Understanding paradoxical stylised facts

Empirical research during the 1980s exhibited the following paradoxical stylised facts. At the microeconomic level, there are persistent diversity and high turbulence in the industrial dynamics within and across industrial sectors, while at more aggregate levels there are significant regularities characterizing industrial dynamics. Industrial dynamics is analysed through specific features such as the persistence of the asymmetric performance of firms, turbulence and industrial demography, firm growth and size distribution (see Geroski 1995, for a general presentation). Firms are intrinsically different in their cost and productivity, profitability, output and innovative strategies (see PRODUCTIVITY). These asymmetries in performance are generally persistent over time. In most industries, however, turbulence in demography is observed through birth and mortality rates. Birth rates are high, entrants are generally new, small and below the efficient minimum scale, but they can also be existing firms operating in other industries or countries. The probability of survival increases with age and depends on the initial size and on growth rates. Mortality rates also tend to be high and turbulence is primarily a characteristic of the fringe of the industry. Concerning growth rates of firms, Gibrat's law states that they are random variables independent of size: the growth rate of a new entrant, being initially large or small, will be driven by a purely stochastic process.

Industry-specific dimensions may complement the preceding firm-specific variables and may be used to assess the regularities observed at more aggregate levels. For instance, asymmetry in performance is in fact a more persistent phenomenon in highly concentrated industries where demand growth is rapid, economies of scale are important, sunk costs are large and advertising expenditures are high. Turbulence differs also drastically across sectors. The general result is that there is a decreasing probability of survival for new and small firms in capital intensive, highly innovative and high economies of scale industries. Finer results appear moreover when the timing of survival is considered. Concentration, economies of scale and capital intensity at the level of the industry increase survival of firms in the short run, but not in the long run. Conversely,

innovation does not affect survival in the short run, but only in the long run, except in industries where small firms are important drivers of innovation. Growth of firms is favoured in innovative industries, especially in early periods after entry.

These empirical findings are paradoxical compared with mainstream industrial organization results (see EVOLUTIONARY THEORIES OF THE FIRM). These empirical observations tend to be inconsistent with the main characteristics of industrial organization models – such as entry positively correlated to supra-normal profits, entry rates explained by specific indicators such as profitability or barriers to entry, average margins of firms linked with entry at the industry level. In this first group of models, the purpose is then, through empirical studies at the industry level or at the national level, to show that conventional theories of industrial organization do not necessarily provide a reliable framework for understanding industrial dynamics. However, the tools used in mainstream industrial organization, namely the definition of optimal properties and the comparative analysis of different equilibrium situations (see *Handbook of Industrial Organization*, edited by R. Schmalensee and T. Willig), remain at the core of the models. As a consequence, industrial dynamics is generally considered in this case to be a sub-domain (counter-intuitive, in most cases) of conventional industrial organization, but the empirical data gathering revealing the puzzles and anomalies do not imply major changes to the analytical framework.

4 Understanding the industry life cycle

This second family of models derives from a hybrid analytical framework: some notions are inspired by mainstream industrial organization, but the global analytical framework is evolutionary-based. As a consequence, the conclusions of this kind of model can be interpreted in different ways. Evolutionary-minded economists, for example, will focus on industry life-cycle studies of the historical path-dependency of firms progressing on a new technological trajectory. Mainstream-minded economists will use this family of models to provide evidence on the industry structure (especially on the interactions between incumbents and new entrants) according to the different phases of the life cycle.

Industry life-cycle models, however, can be considered as an important attempt, not only to define major stylised facts and regularities in the evolution of industries, but also to build a consistent analysis of why and how industries evolve and contribute to economic change. Different major stylised facts and regularities are observed. Production increases in the initial phases of the development of the industry, and then declines; entries are numerous in the beginning and tend to be exceeded by exits over time, especially when a shakeout occurs; market shares are highly volatile in the first steps and become more precisely defined later; product innovation is replaced by process innovation; first movers generally enjoy a long-term leadership; a dominant design and a process of standardization tend to appear over time.

The analytical explanation of industrial change is the following. Industries, like bio-organisms, face different stages during their lifetime, and these stages imply modifications in their characteristics. The first stage begins with the introduction of a new product on the market, either by the inventor or the first producer, and this period corresponds to the emergence of a new industry. At that time, the size of the market is narrowly defined, and there is a high uncertainty on the future growth of this market. The product is like a prototype without any clear definition of applications and, further, of potential demand. This first stage ends with the emergence of new producers (new entrants). The length of this period depends on the size of the market just after the introduction of the product, on the number of potential entrants and on their ability to copy the product innovation. The second stage is characterized by an increase in the number of incumbent producers. Output growth is high and the final design of the product is now available. In the third stage, net entry is around zero. Product innovation is decreasing and is replaced by process innovation. This stage ends with the decline of gross entry rate. The fourth stage involves a negative net entry. The fifth stage reflects the maturity of the market in which a number of incumbent firms exit from the industry: the shakeout occurs.

In this former model (which is based on two initial papers: one by Abernathy and Utterback (1978) that observes some regularities in the evolution of the automobile industry in the USA, and one by Gort and Klepper (1982) that derives empirical observations from forty-six industries), industrial dynamics depends on the changing nature of innovation. From stage to stage, both access to information and profit opportunities condition the innovative behaviour of firms. In the early stages of the cycle, information is freely accessible, opportunities for profits are high, and product innovation is favoured by the entry of new entrants. In later stages of the cycle, incumbents keep the technological information for themselves and enjoy opportunities for profit essentially through process innovation. Entries are decreasing, exits are numerous and a shakeout occurs. The whole sequence of events (entry, innovation, learning and growth) determines industrial dynamics all through the life cycle.

In the late 1980s and 1990s, the analytical content was refined by a series of complementary contributions (see Klepper 1997, for a general presentation) which have either an evolutionary or a mainstream flavour. On the mainstream side, authors focused essentially on the reasons and causes of the shakeout that corresponds to a phase of firms' concentration, and more generally to the emergence of oligopolies. Some of them stress that the

shakeout is directly linked to the dominant design, which is itself a consequence of a rational choice under uncertainty. For others, survival in the phase of shakeout is driven by a stochastic process generated by exogenous technological change. On the evolutionary side, learning and adaptation capacities of firms developed in life-cycle models are used to analyse the process of competition, seen as a selection in a context of endogenous technological change. Moreover, industrial-life cycle models are useful to analyse the link between ‘Schumpeter Mark 1’ evolutionary models – in which entry is easy from a technological point of view, new small firms are the main engines of innovation, technological and competitive advantage of incumbents are progressively eroded – and ‘Schumpeter Mark 2’ evolutionary models – in which entry barriers are high for new small innovators, big incumbent firms are the main engines of innovation, a small number of incumbent firms are leaders in technology and competition. Recent research has been dedicated then to the definition of different cohorts of entrants, developing different innovation capabilities according to their specific dates of entry, and implying different evolutionary models for industrial dynamics.

Empirical studies have improved upon the analytical explanations. For instance, new entrants and latecomers generally survive better than others because the timing of their entry coincides with low exit rates (on stages 1, 2 and 5). However, if new entrants are generally the leaders of the industry, the survival of latecomers is linked with their specialization on specific segments of the industry. The process of competition in which new entrants and latecomers are engaged is primarily driven by technological innovation that necessitates a suitable accumulation of learning and competences over time. Finally and more generally, an industry is deemed not to have experienced a shakeout if the number of firms never declines below 70 per cent of the peak number, or if it does but subsequently recovers to over 90 per cent of the peak. These refinements and empirical investigations reveal an important underlying question: Does the life cycle provide a general model that captures the way many industries evolve? If, for some authors, the answer is positive, others are more cautious about the potential of extension of the model to any industry. Klepper (1997) considers the life-cycle model to apply to only six industries, namely, typewriters, automobile tyres, commercial aircraft for trunk carriers, televisions, television picture tubes and penicillin).

Life-cycle models also have some connections with the national systems of innovation approach. A country can be characterized by a life cycle or, at least, by the age of its leading industries. Inter-country comparisons are then possible regarding the link between innovation and economic growth, according to the respective phases of the life cycle of these countries. Freeman (1989) notices, however, that economic growth cannot be considered as a pure product of the capacity to produce innovations in a country, as is implicitly assumed in life-cycle models. Moreover, unlike the life-cycle models in which a new cycle begins as soon as the new product is launched on the market, technological opportunities cannot be considered as given, but can be constructed in coherence with institutions at the national level. On this point, the work by the various authors in Lundvall (1992) suggests that innovation is dependent on the articulation between different institutional levels (namely, the firm, the industry and the nation), and that this articulation is crucial for innovation to involve economic growth.

The specificity of this second group of analysis is that, at the outset, empirical studies at the industry or national level are not dedicated to illustrating a pre-existing model. The problem is rather to elaborate a new analytical framework of the evolution of industries in which innovation and growth phenomena prevail. This analytical framework in terms of life cycle is based on a biological-evolutionary analogy, and is considered as different – though, for some commentators, possibly complementary – to conventional analysis of industrial organization. This approach confronts the notion that the life cycle can be considered a universal model in which the complex analysis of an evolving economy is then confined to the main regularities presented in life cycle models. If this vision were to be generalized, industrial dynamics will then be reduced to the study of one specific model and, as such, will tend to neglect the wide variety of industrial evolutions observed in the real world.

5 Understanding the evolution of industry

Within the third group of literature, which is more heterogeneous than the two preceding ones, a wider range of questions is analysed (Malerba and Orsenigo 1996): How do products and processes change throughout the evolution of an industry? Who are the new entrants? Are they new firms or are they established firms coming from other industries? How were they able to enter the market? What are their main strategies concerning production, innovation and finance? How do firms develop and modify their capabilities and activities to provide different products and process innovations? How do the boundaries of firms evolve in terms of specialization, vertical integration and long-term relations with suppliers and users? How do these different changes modify the boundaries of the industry? How can these boundaries be defined? How do specific institutions, such as universities, and financial or public institutions contribute to the evolution of industries? Different complementary work – based on different methodologies – is proposed to address these questions, generally with an intellectual background in the study of innovation and economic growth that is different from mainstream economics. In this context, patterns, puzzles and anomalies revealed by empirical work are used to make

progress in the analysis of the forces that drive the dynamics of industry: they are dedicated to opening up the research agenda through a systematic process of validation/refutation of assumptions.

The first type of work intends to determine regular patterns of evolution for industries that do not conform closely to the life cycle. Three different elements can be identified as sources of alternative patterns of evolution: the presence of vertical relationships between suppliers and consumers; the elaboration of horizontal cooperation; and the diversity of demand. If these elements are present (either in isolation or in combination), the main conclusions of life-cycle models are no more valid. For instance, product innovation can persist over time, entry can be spurred even in later stages of the life cycle and dominant design may never exist (Nelson 1998; Langlois and Robertson 1995).

The second type of work provides a detailed historical account of different industries, and elaborates and uses large longitudinal micro-databases. The purpose is to understand the impact of internal organization of the enterprise on inter-enterprise cooperation and competition, as well as on national performance. Connections between different disciplines, especially industrial organization and business history, are necessary. The work is not reduced to a simple reading of economic textbooks in the light of history. It offers a more fruitful perspective, which consists in elaborating empirical economic research programmes in relation to business history. By focusing on the conditions that guide the choices of firms, and not only on the result of these choices, an opportunity is given to get a picture of the competitive dynamics and of the drivers of secular changes in the industry in a way that is different from and very much richer than what comes naturally from the industry-level and even more aggregated data of the conventional statistical sources. Some authors, such as Lazonick (1991), develop then a history-based analysis of the dynamics of firms and industries, especially in an innovative context. Others, such as Lamoreaux, Raff and Temin (1998), make business history accessible to economists in order to improve economic models in terms of information coordination. Detailed case studies on specific industries make more precise the connection between industrial organization and business history: see, for instance, Dosi (1984) on semiconductors; Gambardella (1995) on biotechnology; Fransman (1995) on computers and telecommunications. Malerba *et al.* (1999) suggest that formalizations of the key historical features of industrial dynamics are possible. The basic framework of their 'history friendly modelling' is the development of an appreciative theory which is dedicated to reflecting what the analysts and the empirical researchers believe is really going on, their arguments presenting causal explanations of observed pattern of economic phenomena. The aim then is to build formal models to capture the gist of the appreciative theory put forth by analysts of the history of an industry or a technology. Within this perspective, formal modelling is used to identify gaps in the logic of more informal accounts and to lead to the consideration of mechanisms and factors that initially are missing or muted. The computer industry provides a first example of application of the history-friendly models, but extensions are of course needed to see how formalization can contribute to the extension of the research agenda on industrial dynamics.

Finally, a third type of work investigates the relationship between the evolution of industry and systems of innovations. Nelson (1996) notes that even if globalization stands out as a dominant system, a debate on 'technological-national' specificities still exists. The question is then: how can we characterize systems of innovation in the age of globalization? The answer is not obvious because industrial dynamics may be independent of national institutions. Firms' strategies have a coherence that goes generally beyond the limits of the nation. More generally, globalization involves a conception of firms' strategies in which nations are not the best units of analysis. Systems of innovation and industrial dynamics are based then intrinsically on an economic coherence that has to be investigated in depth. Localization is just an element of this economic coherence, and national systems of innovation are increasingly questioned.

6 Research agenda

Despite the richness and variety of the literature on industrial dynamics, most parts of the research on this theme are still in progress. Innovation and economic growth, which are fundamental notions for understanding industrial dynamics, require the development of new analytical frameworks that are still only emerging, as we have seen in the preceding sections. Three specific issues (at least) can be considered as patterns or regularities of industrial dynamics that researchers have to investigate within the next few years. First, innovation is a complex process that may be either major or incremental, and that generates recurrent and diverse changes on the evolution of industry. Second, entry tends to occur in specific periods of evolution, but not necessarily after the introduction of a major innovation. Third, the evolution of the industry is characterized by different processes of specialization, integration and diversification, which are emerging at specific periods.

7 Conclusion

The challenge of industrial dynamics is to make compatible, on the one hand, detailed and rich empirical knowledge of the evolution of industries and, on the other hand, a sound theoretical framework adapted to this

richness and complexity. To proceed along the path opened up by early authors such as Marshall and Schumpeter, the following tasks are necessary.

- The collection of finer (namely more accurate) empirical evidence on industries, and especially on the homogeneity of the procedure, for the collection of data in order to favour the comparison and confrontation of results.
- The elaboration of taxonomies of industrial evolution in order to define some groups of industries that evolve in a similar way.
- The identification of the main relationships between firms and suppliers, customers, competitors, and more generally governmental, scientific or financial institutions.
- The necessity to propose new definitions of industries, not exclusively related to products or markets, and to infer new propositions to analyse the process of competition in a dynamic setting.
- The understanding of the link between the evolution of industries, innovation and economic growth, and their implications at the local, national or international level.

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Further reading

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See also: AEROSPACE INDUSTRY; AUTOMOBILES INDUSTRY; BIOTECHNOLOGY; CHEMICALS INDUSTRY; COASE, R.; COOPERATION AND COMPETITION; CORPORATE CONTROL; DEVELOPMENT AND DIFFUSION OF TECHNOLOGY; ECONOMIC GROWTH AND CONVERGENCE; ELECTRONICS INDUSTRY; EVOLUTIONARY THEORIES OF THE FIRM; GROWTH OF THE FIRM AND NETWORKING; INDUSTRIAL AGGLOMERATIONS; INSTITUTIONAL ECONOMICS; MACHINE TOOLS; MARSHALL, A.; MARX, K.; PRODUCTIVITY; SCHUMPETER, J.; SMALL AND MEDIUM ENTERPRISES; SMITH, A.; STEEL INDUSTRY; TELECOMMUNICATIONS; THEORY AND HISTORY; TRANSACTION COST ECONOMICS; WILLIAMSON, O.E.